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A Synthesis of Research on the Human Dimensions of Sagebrush Ecosystem Management ☆

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ABSTRACT

To protect species of concern in rangeland systems, managers and policy makers must understand the human dimensions of the ecosystems those species rely on. Sagebrush (*Artemesia* spp. L.) ecosystems are among the most extensive rangelands in the western United States and have been of particular concern in recent years due to the decline of greater sage-grouse *(Centrocercus urophasianus)* and other sagebrush obligate species. While there is a substantial body of literature on the biophysical aspects of sagebrush ecosystems, the human dimensions of sagebrush management are not well understood and social science research is distributed throughout a wide range of journals and disciplines. We used systematic review principles to conduct a synthesis of literature to assess existent knowledge on the human dimensions of sagebrush management and conservation and to identify areas for future research. We cast a broad net to include studies from economics, political science, social psychology, sociology, governance, anthropology, and other fields. Using Web of Science and search terms sourced from our research questions and relevant stakeholders, we identified 78 studies meeting the following criteria: 1) the research was conducted within the distribution of North American sagebrush and 2) the research included social science methods. We coded the 78 studies to identify the focus of research on resource issue(s), social issue(s), geographical region, and additional research needs. The literature focused on resource issues primarily related to fire, land use, sage-grouse, and rangeland management, while social issues emphasized collaboration, stakeholder perceptions and attitudes, and modes of governance. Research gaps include assessments of the longevity and ecological impacts of collaboration, perceptions and attitudes surrounding wild horse and burro management, and governance approaches to managing invasives and ecological restoration. Research that includes input from Native Nations is lacking, and inclusive social science relevant to diverse stakeholders in sagebrush is overdue.

Introduction

Rangelands in the American West host a diversity of environments and people, but perhaps no organism is more associated with the West than sagebrush (*Artemisia* spp. L.). Sagebrush is both a genus of plants that are found across the region and the name for the biome that they dominate, often called the sagebrush steppe (**Fig. 1**). Sagebrush presents distinct management challenges including balancing multiple uses, such as grazing and recreation, mitigating wildfire risk and invasive plants, and maintaining viable economies while supporting cultural preservation (Davies et al. 2011; Showalter 2015). This biome supports food production including ranching and farming, significant wildlife populations, substantial energy extraction, and critical ecosystem services for its inhabitants (Bennett and Suhr Pierce 2021). Resource productivity in sagebrush is diverse and extensive, but concerns about sustainable land use have increased in recent decades (Huntsinger and Hopkinson 1996; Showalter 2015).

The North American sagebrush steppe has been reduced to approximately 50% of its historic range (Pyke et al. 2015). Some populations of sagebrush-obligate species have declined due, in part, to this habitat reduction and fragmentation (Davies et al. 2011; Conover and Roberts 2016). Declining greater sage-grouse (*Centrocercus urophasianus* Bonaparte) populations through the 20th century and the potential of sage-grouse listing under the

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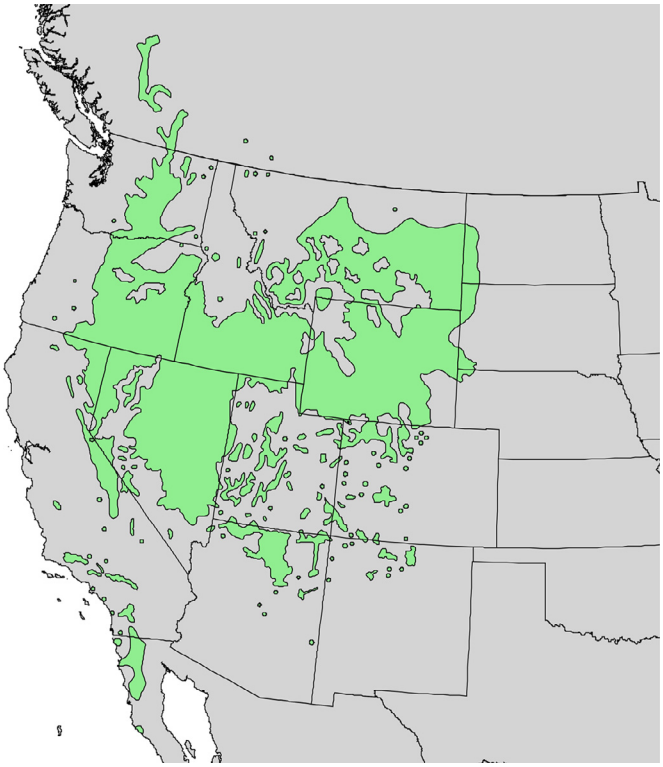

Figure 1. Map of the distribution of sagebrush (*Artemisia tridentata* L.) (Little 1971).

Endangered Species Act (ESA) instigated a western US regional collaboration to conserve the species (Showalter 2015; Naugle et al. 2020). Regional collaboration has worked to develop management plans with the goal of maintaining and increasing sage-grouse populations (Remington et al. 2021). While this collaborative initiative has substantially increased research on the biophysical nature of sagebrush and the species that rely on those habitats, social science research assessing the human dimensions of sagebrush management and conservation is lacking (Bennett et al. 2019).

Human dimensions of the environment and natural resources is an overarching concept that includes a range of social disciplines that study human processes, society, behavior, and relationships often through a scientific approach (i.e., social science)[1] (Bennett et al. 2017; Spalding et al. 2017). Researchers have long called for genuine incorporation of social science and human dimensions in conservation and resource management to improve ecological outcomes (Endter-Wada et al. 1998; Jacobson and McDuff 1998; Bennett et al. 2017; Guerrero et al. 2018; Sayre 2004). Understanding the human dimensions of ecosystem management is critical to successful conservation. Failure to account for human dimensions in ecosystem management and planning can alienate stakeholders, ignore important factors in ecosystem degradation, and overlook vital tools that could improve outcomes, resulting in suboptimal management strategies (Huntsinger and Hopkinson 1996). Taking human dimensions into consideration allows for a better understanding of the motivations behind human behavior. Management plans and conservation efforts can then capitalize on those motivations or be informed by social science insights (Huntsinger and Hopkinson 1996; Bennett et al. 2019; Sayre 2004).

[1] We use the terms "human dimensions" and "social science" synonymously but recognize that some scholars distinguish human dimensions as also including the humanities (e.g., the arts, philosophy), fields that do not apply scientific approaches to understanding social phenomenon (Spalding et al. 2017).

Social science relevant to North American rangelands has increased in the past few decades. Bruno et al. (2020) systematically mapped rangeland social science in North America and showed that the number of journal articles published between 1970 and 2017 increased substantially from just 3 articles published between 1970 and 1979 to 158 articles published between 2010 and 2017. They found this body of research largely focused on ranchers, landowners, and farmers, while few studies focused on indigenous stakeholders. Gender, race, and ethnicity were rarely a focus of research, and relative to biophysical studies, there is a limited body of research assessing the human dimensions of rangelands. Bruno et al. (2020) also indicate a need for incorporating intersections in identity (e.g., indigenous women) and expanding research collaboration to include more and intersecting disciplines.

While the increase in research on the human dimensions of rangelands is promising, the extensive geographic scope of rangelands can restrict the research to broad-spectrum assessments rather than ecosystem-specific analysis that can support targeted management. Emerging research is demonstrating the value of social science to informing ecosystem management and improving ecological outcomes. While incentives have been researched as means to propel conservation on private lands, some studies show that landowners have diverse motivations that need to be considered in developing and implementing conservation programs (Cross et al. 2011; Sorice et al. 2012; Sorice et al. 2013). In one species-specific study, researchers found that direct payments were not the primary driver to incentivize private landowners to participate in conservation measures (Ramsdell et al. 2016). To prevent the listing of mountain plover (*Charadrius montanus* Townsend) under the ESA, the Rocky Mountain Bird Observatory (RMBO) launched a conservation program that paid farmers to identify and avoid plover nests on privately owned agricultural fields in Nebraska. Social science researchers assessed participants' motivations for engagement and found that most farmers were intrinsically motivated by the desire to be a good steward of the land. Furthermore, most participants indicated they would continue to participate in plover conservation if financial incentives were removed (Ramsdell et al. 2016). As a result, RMBO has been able to focus available funding on expanding research programs. This conservation initiative is lauded as a contributing factor in preventing the species from being listed under the ESA (Ramsdell et al. 2016). While this is just 1 example, it illustrates how social science can contribute to improved ecological outcomes in conservation initiatives.

We conducted this review to synthesize the social science research focused on the North American sagebrush biome. This synthesis is part of a broader research project to understand the social science needs for managing and conserving sagebrush. Other components of this broader research included surveys, interviews, and focus groups conducted in 2018 and 2019 (Bennett et al. 2019). We conducted this literature review according to systematic mapping approaches, which use reproducible review methods to identify and synthesize a field of research, as well as a subset of the studies identified (Gough et al. 2012; Berrang-Ford et al. 2015). Our goals were to characterize and synthesize existing social science research relevant to sagebrush ecosystems and identify human dimensions research needs and priorities to guide sagebrush management and conservation. This synthesis provides a cohesive understanding of social science research conducted in the sagebrush biome, is an additional step in advancing human dimensions work to complement advances in biophysical sciences, and can serve as a model for biome-specific assessments elsewhere. In conducting this synthesis, we were guided by the following research questions:

1. What is the scope of existing social science research relevant to the management and conservation of sagebrush ecosystems

Table 1
Search terms for Web of Science search concluded October 2018 to identify social science research in the North American sagebrush biome.

First	Second	Third
sage*	range*	manage*
sagebrush*	eco*	social*
rangeland	'human dimensions'	use*
'sage grouse'	land*	conserv*
	conserv*	US
	steward*	America*
	percept*	West
	accept*	
	social*	
	partner*	
	attitude*	
	collabora*	
	econ*	
	institut*	
	govern*	
	participat*	
	integrat*	
	use*	
	valu*	
	'social eco*'	
	'public land*'	
	incentiv*	
	privat*	
	place*	
	adapt*	

in terms of geographic focus, methods used, and the social and resource issues addressed?
2. Does existing sagebrush social science research identify specific research gaps or needs to guide future research?
3. What insights does previous social science research provide to sagebrush management and conservation?

Methods

Our literature review followed principles of systematic methods (Pullin and Stewart 2006; Gough et al. 2012; Berrang-Ford et al. 2015; Bruno et al. 2020). Although systematic methods can be limited by the journals indexed by search engines and search terms selected by researchers, systematic maps can provide robust and transparent approaches to reviewing and synthesizing research on a topic. Systematic methods also minimize bias by establishing clear and reproducible protocols (Pullin and Stewart 2006; Randall and James 2012). Reviews that use systematic methods typically aim to answer specific and relatively narrow research questions, often with the intent of providing evidence to practitioners. Alternatively, systematic maps can be used to broadly characterize literature, such as quantitatively assessing topics addressed and methodologies used (Gough et al. 2012; Randall and James 2012). Given our broad focus on social science informing sagebrush management and conservation, we used a systematic mapping approach aligned with recent systematic maps with similar scope and focus (e.g., Bruno et al. 2020).

We created a standardized protocol for identifying and extracting data from relevant literature. We used Web of Science to search the literature using a set of search terms developed from our research questions and stakeholder input and expanded those search terms using key words from known relevant literature. We cast a broad net to include studies from economics, political science, social psychology, sociology, governance, anthropology, and other social science fields. Example search terms include sage* govern*; rangeland* 'human dimensions'; 'sage grouse' collabora*. **Table 1** lists the full set of primary, secondary, and tertiary search terms. Results for each set of search terms are available in the supplementary material.

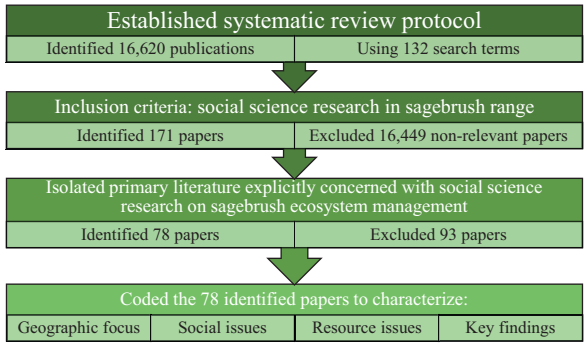

Figure 2. Flow chart illustrating methods for the systematic literature review of social science research in the North American sagebrush biome.

Our initial search (sage*) yielded 16,620 papers. We developed additional primary search terms from our research questions and refined our search by adding secondary and tertiary search terms until we isolated relevant and manageable results. For each search iteration we determined relevancy by analyzing the paper titles, then abstracts for the first 100 results or 10% of results, whichever was greater. If those results identified 3 or more new papers, we analyzed the entire results list. We continued this iterative process until our search terms yielded redundant literature, indicating we had reached saturation and new search terms were unlikely to materially expand the identified relevant literature (Saunders et al. 2018; Bruno et al. 2020). Our final search totaled 132 unique combinations of search terms. We only included journal articles from peer-reviewed journals published in the English language and indexed by Web of Science. We excluded gray literature, books, and conference proceedings to minimize bias in literature identified and because of the challenges in accessing some of these materials. Our screening of search results, concluded in October 2018, identified 171 potentially relevant papers (**Fig. 2**). Additional relevant studies have been published after our search window that may fill some of the identified research gaps described in the discussion section.

We examined the 171 identified papers to ensure they met the following inclusion criteria: 1) the research was conducted within the range of North American sagebrush (see Fig. 1), 2) the research included a social science component, and 3) the research was relevant to sagebrush management. Of the 171 papers, 78 met these criteria and included quantitative and qualitative research (see Fig. 2). A list of all papers meeting the inclusion criteria is available in the supplementary materials.

We used a modified social-ecological systems framework to code the topics addressed in the literature (Ostrom 2009; Basurto et al. 2013; McGinnis and Ostrom 2014). We initially coded for many variables, but in the interest of generating digestible results we pulled back from highly detailed coding and created more generalized categories for analysis. We coded the 78 papers to characterize the geographical region, resource issue, and social issue covered, as well as study method used. For quality assurance, each coder checked the others' assessment. Discrepancies were resolved by comprehensively analyzing the paper and/or consulting a broader research team. We used an open coding approach to code resource and social issues and then grouped similar codes together to create broader categories. For example, through the open coding approach, if one researcher coded a study as focused on "Greater sage-grouse" and another researcher coded a study as focused on "Gunnison sage-grouse," we later grouped these into a broader category of "sage-grouse." We include definitions for the resource and social issues in **Table 2**.

Table 2
Resource and social category definitions for a synthesis of the social science literature relevant to ecosystem management in the North American sagebrush biome.

Resource category	Definition
Wild horses & burros	"unbranded, unclaimed, free-roaming horses or burros found on public lands in the United States" (Bureau of Land Management)
Carbon sequestration	Capture and storage of atmospheric CO_2
Climate change	Long-term changes to average climactic conditions including temperature and precipitation
Drought	Prolonged reduction in precipitation resulting in water shortage
Ecosystem services	Contribution of ecosystems to human health and well-being
Invasive plants	Non-native species that compromise or reduce native plant productivity/diversity
Fire	Both wild and prescribed combustion of vegetation and fuels management
Ecological restoration	Reestablishment of native communities of plants and animals, facilitating a native ecological trajectory
Biodiversity	Diversity of life in a designated region/ecosystem
Grazing	Feeding of domestic livestock for agricultural production and management/assessment of available forage for domestic livestock production
Land use	Economic and cultural activities, such as agriculture, residential, or recreational uses, at a given place. (Environmental Protection Agency)
Sage-grouse	*Centrocercus* species–upland, ground–nesting, sagebrush obligate birds
Rangelands	Landscapes predominantly not forested, cropland, ice covered, or inhabited as cities that can support wild and domestic grazing animals
Social category	
Local knowledge	Insights into ecosystem management from the people who live on and work the land
Outdoor recreation	Activities and land uses undertaken for pleasure in nature-based environments; both motorized and nonmotorized
Adaptive management	Management strategies that implement structured and iterative decision-making processes to adjust with uncertainty over time
Conservation practices & incentives	Land management practices implemented with the goal of enhancing or maintaining environmental conditions and the rewards provided to encourage practice adoption (e.g., financial payments, social recognition)
Economics	Focus on markets, prices, economic activity, and other economic dimensions
Other actor attributes	Characteristics of actors not captured by other social categories such as the influence of place identity or political orientation on land management
Resource management	Broad category where there is a social dimension and clear management focus that is not captured in other social categories
Collaboration	Processes intended to foster joint work and interactions among diverse stakeholders to identify and/or pursue common interests
Decision making	Focus on individuals or group processes and influences on decisions
Perceptions & attitudes	Individuals' thoughts and their influence on behaviors in the context of social settings
Governance	Formal and informal rules, policies, or social norms that influence how people interact with the environment or each other

After coding the papers, we constructed a matrix to assess overlap between resource and social issues (**Fig. 3**). We then synthesized key findings and insights from studies addressing the top social science issues and with at least three papers overlapping with a resource issue. We emphasize those findings in the discussion. We focus on these areas of overlap to identify insights from social science research on topics that have received more emphasis in the literature.

To identify research gaps, we cross referenced our results with findings from Bennett et al. (2019), which summarizes insights from diverse stakeholders throughout sagebrush range. This information was compared with suggestions for additional research from the identified literature and Bruno et al. (2020).

Results

Much of the literature addressed multiple geographical regions, used mixed methods, and assessed numerous social and/or resource issues. These results counted all regions, methods, and issues in every paper, and thus the sums listed in these categories exceed the total number of papers included in this synthesis.

Geographic focus, methods, and social and resource issues

We identified geographical regions from a national scale down to the state a study focused on. Of the 78 papers identified, 19 had a regional focus on the western United States (spanning the states of Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming), 15 were focused in Utah, 12 in Oregon, and 6 had a national scope, which included a significant component directly relevant to the sagebrush biome. Colorado, Idaho, and Wyoming were each represented with 9 papers, and California and Montana constituted 4 papers each. Three papers were focused on Nevada and two on Washington (**Fig. 4**).

We categorized methods first as quantitative, qualitative, or both, and then by the specific study method used. Quantitative methods were used in 50.6% of the research, qualitative methods were used in 35.1% of the studies, and 14.3% of the research used a combination of quantitative and qualitative methods. Surveys were the most common method representing 26.4% of the literature. Interviews comprised 22.6% of the methods, case studies accounted for 20.8%, document analysis constituted 8.5% of the research methods, economic modeling comprised 7.5%, and policy analysis and literature review each represented 3.8% of the studies. Stakeholder workshops were used in 2.8% of the papers while 1.9% used spatial analysis, and participatory mapping and Q-study methodology were each used in 0.9% of the research (**Fig. 5**).

Twelve social issues emerged from our identified body of literature. Governance was the most researched social issue representing 17.2% of this body of literature. Studies on stakeholder perceptions and attitudes constituted 15.5% of the literature, decision making 12.1%, collaboration 11.2%, and economics, other actor attributes, and resource management each represented 8.6% of the research. Conservation practices and incentives comprised 5.2% of the literature, adaptive management 4.3%, outdoor recreation 3.4%, local knowledge 2.6%, political movements 1.7%, and energy development was researched in 0.9% of the studies (**Fig. 6**).

Resource issues identified in our body of literature spanned 13 categories. Rangeland, defined as landscapes not predominantly forested, cropland, ice covered, or inhabited as cities that can support wild and domestic grazing animals (Sayre 2017), represented 16.9% of the identified literature. Sage grouse and land use each comprised 14.6% of the literature, and 13.5% was focused on grazing. Biodiversity was assessed in 7.9% of the studies, and fire and ecological restoration each accounted for 6.7% of the research. Invasive species were studied in 4.5% of the research, and studies assessing climate change, drought, ecosystem services, and carbon sequestration each represented 3.4% of the literature. Social science related to wild horses and burros represented 1.1% of the research (**Fig. 6**). Definitions of social and resource categories are presented in **Table 2.**

Social Issues

Resource Issues	Political movements	Local knowledge	Outdoor Recreation	Adaptive management	Conservation practices & incentives	Economics	Other actor attributes	Resource management	Collaboration	Decision Making	Perceptions & attitudes	Governance
Wild horses & burros						1						1
Carbon sequestration											3	
Climate change				1			1			2	1	
Drought				1			1			2	2	
Ecosystem services					2					1	1	
Invasives						1		2		1	2	
Fire						2				1	2	4
Ecological restoration	1						1	3	2	1	1	
Biodiversity					2		2	3	2	2		1
Grazing			1	1		4	1	2	1	2	2	3
Land use	1		2			1	4			2	4	5
Sage-grouse		1	1		2			1	7	1	1	5
Rangelands		2		2	1	2	2	2	3	2	2	4

Figure 3. Matrix identifying the numbers of papers overlapping social and resource issues in sagebrush social science research ($n = 78$).

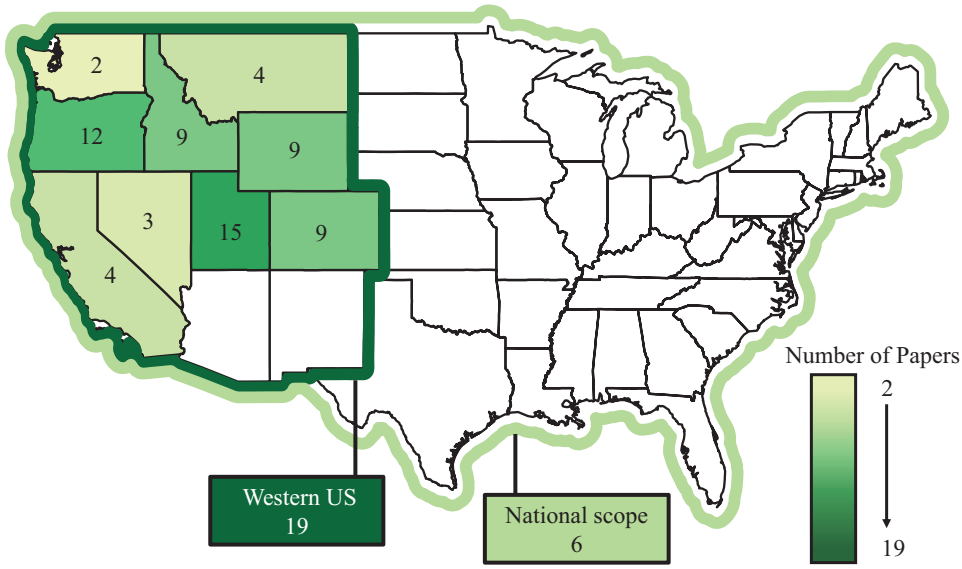

Figure 4. Geographic distribution of social science research in sagebrush ecosystems ($n = 78$).

Overlap

Our analysis also identified overlap between geographical study area and resource issues and overlap between resource and social issues. The greatest overlap between research regions and resource issues was studies on rangelands in the western United States (six papers), grazing in the western United States (five), land use in the western United States (five), and research on rangelands with a national scope (three). Fire was researched most frequently in Idaho (four) and Oregon (three). Governance in the western United States was the most frequent overlap in regional and social issues researched (eight), followed by economics in the western United States (five), perceptions and attitudes researched in Utah (five), and governance on a national scope (four).

Overlap between resource and social issues guided our discussion in this paper. We found the greatest overlap in resource and social issues to be on sage-grouse and collaboration (seven). The second-highest level of overlap was between land use and governance (six), followed by sage-grouse and governance (five), with four papers each in governance and fire, governance and rangelands, and perceptions and attitudes and land use. We identified resource categories where there is little or no research to include

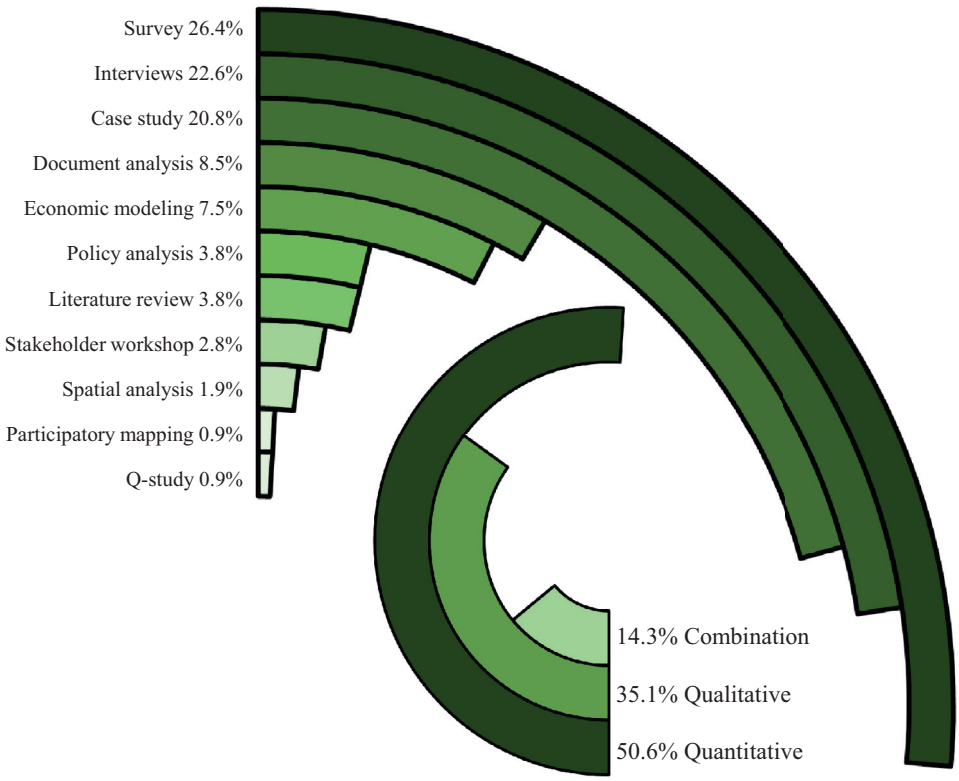

Figure 5. Methods used in social science research in the North American sagebrush biome ($n = 78$).

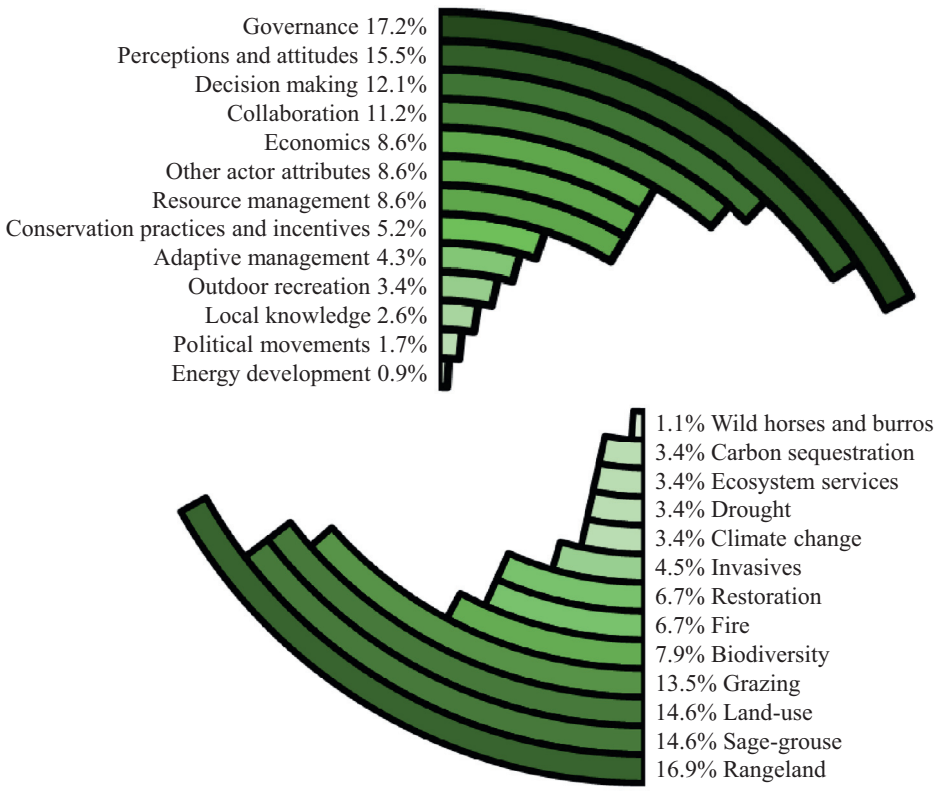

Figure 6. Social and resource issues identified in research on human dimensions of sagebrush management ($n = 78$).

wild horses & burros, carbon sequestration, climate change, and drought, which are lacking in nearly every social category. Little research exists on social issues including political movements, local knowledge, outdoor recreation, or adaptive management overlapping with most or any of the resource categories (see Fig. 3).

Discussion

This discussion focuses on the social issues most prevalent in the literature, which included governance, collaboration, and stakeholder perceptions and attitudes. Next, we synthesize the studies addressing these topics and gaps in the literature. We focus on the resource issues that predominately overlapped with the most prevalent social science topics and discuss their relevance to sagebrush management and conservation.

Governance

A common theme that emerged was a focus on local involvement in decision-making processes. Research related to sage-grouse management cited a need for stakeholder agency in management strategies, implementation of regulatory measures, and long-term monitoring (Birdsong 2005; Toombs and Roberts 2009; Boyd et al. 2014; Knapp et al. 2015; Abrams et al. 2017; Stasiewicz and Paveglio 2017; Wollstein and Davis 2017; Abrams et al. 2018). Several studies examined governance approaches that support local livelihoods and lifestyles by increasing local stakeholder involvement and interagency collaboration around sage-grouse conservation (Knapp et al. 2015; Brymer et al. 2016; Wollstein and Davis 2017). These approaches were also seen as a likely path toward improved ecological outcomes through increased local buy-in.

One-quarter of the governance research focused on fire management in sagebrush and strategies to involve local stakeholders to improve social and ecological outcomes (Yoder et al. 2003; Abrams et al. 2017; Stasiewicz and Paveglio 2017; Abrams et al. 2018). Specifically, the formation of Rangeland Fire Protection Associations (RFPAs) in eastern Oregon and western Idaho significantly reduced conflict between stakeholders and agency managers (Abrams et al. 2017; Stasiewicz and Paveglio 2017; Abrams et al. 2018). RFPAs are landowner groups trained as volunteer firefighters and authorized to respond to wildfire. RFPAs have contributed to rapid containment of wildfire that threatens homes and infrastructure on working landscapes while supporting local stewardship of the land. Issues concerning the hierarchy of decision making arose in some studies, citing a need for better communication between agency representatives and stakeholders before a wildfire ignites and during containment (Wollstein and Davis 2017). Improved collaboration in fire governance, supported by communication avenues established in the formation of RFPAs, can also lead to better preventative management, improved trust between agencies and stakeholders, and ultimately a reduced fuels load and reduction in potential for catastrophic wildfires (Stasiewicz and Paveglio 2017; Abrams et al. 2018, 2017).

Research into governance on rangelands also cited collaborative agency-stakeholder relationships as a means of incentivizing stewardship, which can lead to increased rangeland productivity (Knapp et al. 2015; Wollstein and Davis 2017). Private ranch lands are often associated with leased public grazing allotments, and, as such, ranchers are often stewards of public lands. Government budgets are typically insufficient to meet management needs on sagebrush rangelands, indicating a crucial role of ranchers in maintaining healthy rangelands across public and private boundaries (Brunson and Tanaka 2011; Pyke et al. 2015; Chambers et al. 2017). Furthermore, governance on rangelands has historically held livestock management separate from wildlife habitat management (Toombs and Roberts 2009). By reorganizing funding allocation and management objectives to enhance the heterogeneity of vegetative structure across the landscape, governance can better manage these intersecting needs on rangelands (Toombs and Roberts 2009).

Collaboration

Research on collaboration focused on the structure and function of Local Working Groups (LWGs) formed for sage-grouse conservation. Six studies concluded that a neutral facilitator was critical to successful LWG conservation plan development and implementation (Belton and Jackson-Smith 2010; Belton et al. 2017; Boies 2017; Christiansen and Belton 2017; Cochran et al. 2017; Duvall et al. 2017). Neutral facilitators assured participants that all considerations would be represented, and the facilitators were able to conduct LWG meetings efficiently (Boies 2017; Christiansen and Belton 2017). Additional factors contributing to successful LWG conservation initiatives include initial collaborative work focused on building trust between actors and thoughtfully structured membership expectations and requirements (Belton and Jackson-Smith 2010; Brymer et al. 2016; Boies 2017; Christiansen and Belton, 2017). One example from the Gunnison Basin of Colorado described both successful and unsuccessful structures (Cochran et al. 2017). Initial LWG format lacked structure in membership and decision-making processes, which led to insubstantial results. Reformation of conservation planning into a strategic committee with structured membership requirements and a well-defined decision-making process informed by subcommittees of specialists resulted in successful outcomes. These outcomes include an effective functioning structure, a decision-making process that is accessible to public scrutiny, and increased LWG reputability, which strengthened collaborative relationships with governmental agencies (Cochran et al. 2017).

The research found that a focus on consensus-building and democratic processes are additional factors important for successful collaboration (Belton and Jackson-Smith 2010; Belton et al. 2017; Christiansen and Belton 2017; Cochran et al. 2017; Duvall et al. 2017). By providing a platform for all members to voice their opinions and have substantive input in the decision-making process, LWGs can unify stakeholders and approach initiatives with strong local support. Some research found that a sense of ownership over collaborative plans is foundational to the dynamics leading to successful LWG initiatives (Belton and Jackson-Smith 2010; Belton et al. 2017). Use of democratic processes and consensus-building in the decision-making process may facilitate that sense of ownership among members. While consensus is an important focus, it often lengthens the decision-making process and can lead to stagnation (Cochran et al. 2017). By formatting the collaborative process to allow for decisions made by a majority vote when consensus is elusive, LWGs can maintain forward motion (Cochran et al. 2017).

In addition, when locals are included in research, science is demystified (Belton and Jackson-Smith 2010). As a result, people affected by conservation plans are more likely to trust, accept, and support those initiatives. Local knowledge is also an important factor in research and modeling for conservation planning. Researchers in Washington state improved the accuracy of models and built positive and trusting relationships with local stakeholders when local knowledge pertaining to ecosystem processes and dynamics was included in the scientific process (Beall and Zeoli 2008).

One factor found to hinder successful LWG planning was rapid turnover in agency personnel (Boies 2017). Other research found power-sharing to be foundational to successful LWGs (Belton and Jackson-Smith 2010). Conservation initiatives developed across private and federal land in Nevada lost ground in their planning process when new agency personnel were appointed to the man-

agement unit (Boies 2017). When collaborators have worked to develop a conservation plan, starting at the beginning in building trust with a new agency representative can undermine LWG initiatives or, at the least, postpone action (Belton and Jackson-Smith 2010; Brymer et al. 2016; Boies 2017; Christiansen and Belton 2017; Cochran et al. 2017; Duvall et al. 2017).

Perceptions and attitudes

Stakeholder perceptions and attitudes were studied across resource issues including fire, invasives, rangelands, grazing, sage-grouse, and land use. Land-use studies focused on shifts in land ownership and demographics in Colorado, Utah, and Wyoming (Theobald et al. 1996; Messmer et al. 1998; Kreuter et al. 2006; Mealor et al. 2011). The research sought to understand the perceived impacts of land-use changes on ecosystem services and identified concerns among residents about land-use changes resulting in smaller land parcel sizes and increased landscape fragmentation (Theobald et al. 1996; Kreuter et al. 2006; Mealor et al. 2011). This body of research found landowner perceptions and attitudes are affected by family history on the land, personal ownership rights, awareness of management concerns, and prevalence of public lands in the region (Theobald et al. 1996; Messmer et al. 1998; Kreuter et al. 2006; Mealor et al. 2011).

In states where public lands comprise significant portions of the landscape, landowners have a greater sense of duty to undertake management actions that are socially acceptable and/or maintain ecosystem services (Kreuter et al. 2006). As the goals and interests of private landowners in sagebrush evolve, maintaining ecosystem services may be accomplished by supporting new markets including state-facilitated hunter access programs. In Utah, these programs were found to conserve and improve wildlife habitat while supporting open spaces (Messmer et al. 1998).

Landscape fragmentation from subdivision is a concern throughout sagebrush range (Theobald et al. 1996; Mealor et al. 2011). In one study of the East River Valley in Colorado, residents reported concerns about landscape fragmentation and its negative impact on traditional ranching culture and a change in the valley's "sense of community" (Theobald et al. 1996). Population growth and landscape fragmentation compromised grazing practices and the movement of livestock through increased traffic and antagonism from new residents and established visually unappealing developments where open space and cattle once dominated (Theobald et al. 1996). While subdivision reduced available affordable housing, residents also perceived development as leading to an increase in higher-paying jobs and improved local amenities (Theobald et al. 1996).

An assessment of exurban landowner perceptions and attitudes in Wyoming did not support researchers' prediction that new exurban residents are ignorant of sustainable land management. Instead, the researchers found overgrazing and invasive plant encroachment were not positively correlated with smaller land-parcel sizes (Mealor et al. 2011). While new rangelands residents and ranchette owners were found to practice sound land management methods, monetary investment, rather than social responsibility, drove decision making (Mealor et al. 2011). Outreach programs to inform new landowners about proactive land management methods can be beneficial to combating invasives and mitigating wildfire, but the outreach methods and materials should be multi-pronged, tailored to the appropriate demographic, and consider relevant drivers in decision making (Mealor et al. 2011).

Identified gaps

Beyond our synthesis of existent research, we also identified the following social and resource issues that were absent or had limited representation in the body of literature: We did not find substantial research into the human dimensions of wild horse and burro management—a contentious and pressing issue in sagebrush ecosystems. Cooperative federalism, the flexible collaboration between federal and state or local entities, related to wildfire in Oregon and Idaho has been researched. However, our understanding of this mode of governance is lacking in other regions and resource issues. We also found little social science research in sagebrush focused on energy development, ecosystem services, local knowledge, invasive plant management, conservation practices and incentives, and climate change. In addition, the lack of research explicitly identifying stakeholders from marginalized communities in conjunction with findings from Bruno et al. (2020) indicates that what research has been conducted may suffer from bias in the type of stakeholders engaged and topics addressed.

While substantial research has assessed successful collaboration in sagebrush, assessments of the functional structure, limitations, and longevity of collaborative agreements are limited (Bennett et al. 2019). The overwhelming majority of research on collaboration in our identified body of literature is centered on sage-grouse conservation (Belton and Jackson-Smith 2010; Brymer et al. 2016; Boies 2017; Christiansen and Belton 2017; Cochran et al. 2017; Duvall et al. 2017). Research on collaboration focusing on different resource issues may help identify broad themes and resource-specific collaborative needs. In addition, long-term assessments of the ecological outcomes achieved are needed to better assess the impact of collaborative efforts on sagebrush ecosystems and would benefit from integrated social-ecological approaches.

Social science research on wild horses and burros is a major gap for addressing this pressing issue in the West. This topic is highly contentious, with divergent stakeholder perceptions and attitudes often leading to conflict (Scasta et al. 2018). Biophysical research indicates a need to better manage the animals and their habitats and shows that limited management capabilities result in poor outcomes for not only sagebrush ecosystems but also wild horses and burros (Scasta et al. 2018). Research seeking to understand the assumptions and values underlying different perceptions and attitudes may help to inform better outreach and management strategies that are conducive to healthier ecosystems and wildlife.

Improving ecosystem function will also require better management of invasive plants. Research on governance approaches to managing invasive species and related to ecological restoration are areas where additional social science is needed. Considering the correlation between invasive annual grass encroachment and wildfire, longer and more severe wildfire seasons, and the success of Rangeland Fire Protection Associations in mitigating wildfire, social science research into governance related to invasives could substantially improve ecological outcomes (Brunson and Tanaka 2011). In addition, ecological restoration has the potential to mitigate the encroachment of invasive grasses, thus reducing potential for wildfire and supporting populations of native species (Gordon et al. 2014; Pyke et al. 2015; Chambers et al. 2017).

We concluded our literature search in 2018, and our search methods did not include gray literature or journals not indexed by Web of Science. Some literature published since late 2018 begins to address some of the gaps we identify, as do some papers not identified by our search methods. For example, one paper from the journal *Rangelands* (a journal not indexed by Web of Science) assessed the potential for volunteers to enhance invasive weed encroachment. This study identified younger, educated stakeholders as potential sources for control of invasives (Tidwell and Brunson 2008). A different study published after our search was concluded assessed rancher decision making related to ecosystem services (York et al. 2019). Another paper published in 2019 explored climate change–related challenges for first-generation livestock pro-

ducers (Munden-Dixon et al. 2019). This increase in literature is promising, and we hope additional studies continue to fill identified gaps, especially those related to inclusivity.

Our initial analysis extracted social and economic actor attributes, but less than half of the studies included sufficient data to enable coding for this variable. Most references to study populations simply cited rural agricultural communities as the focus, so we were not able to analyze demographic data. Previous research identified the primary stakeholders represented in rangelands social science to be ranchers, farmers, and landowners (Bruno et al. 2020). On the basis of the absence of diverse stakeholders in our findings, we conclude that the research analyzed in this paper largely focused on similar types of stakeholders. The people of the West are as diverse as the landscape, but social science research has focused overwhelmingly on landowners and ranchers. Land ownership in the West is inextricably linked to white-settler colonialism, which, by default, excludes racialized stakeholders (Inwood and Bonds 2017). It is important to recognize the critical role landowners and ranchers play in maintaining open landscapes, stewarding the land to preserve biodiversity and ecosystem services, and generating economic activity, but there are many relevant stakeholders and demographic groups that are not the focus of existent social science research. We found limited research on outdoor recreationists, hunters, tourists and the workers who sustain tourism industries, female stakeholders, seasonal agricultural laborers, and no research specifically focused on Black, Indigenous, or People of Color.

Indigenous representation in our pool of social science studies was nearly absent. Sagebrush has been home to tribes for millennia (Bennett and Suhr Pierce 2021), and significant portions of sagebrush lie within Native Nations, yet Indigenous perspectives and insights were not represented in the body of sagebrush social science we analyzed. We found one paper not indexed by Web of Science that addressed the historical impact of native communities on Yellowstone National Park, but that paper did not include insights from present-day Native Nations (Yonk et al. 2018). We did find two papers outside of our inclusion criteria. One paper focused on the history of prescribed burning in sagebrush by Indigenous Peoples before colonization (McAdoo et al. 2013) but was excluded from our analysis since it relied on biophysical analyses and did not incorporate social science methods. The second paper assessed rangeland management collaboration with Tohono O'odham on tribal rangelands, a region outside sagebrush range (Arnold and Fernandez-Gimenez 2007). In addition, two papers that fit our criteria have been published after our search was concluded, one on traditional ecological knowledge on the Wind River Reservation and a second assessing productivity on rangelands across ownership groups including tribal lands (Robinson et al. 2019; Friday and Scasta 2020). This recent increase in literature focused on Indigenous Peoples and tribal lands is encouraging. We strongly recommend future social science research focus on diverse stakeholders by considering the demographics of respondents and study groups and include underrepresented voices, especially those of Black, Indigenous, and People of Color.

Implications

Substantial ecological problems face the American West, from invasive plants to wildfire, habitat fragmentation to reduced productivity in rangelands. These issues point to a need for additional targeted and cohesive research into biome-specific social science. While the body of social science research in the sagebrush biome is expanding, that research is distributed across a wide variety of journals and disciplines, lacks broad geographic coverage, and is focused on a narrow range of stakeholders. Land and wildlife managers throughout the West indicate a need for increased knowledge about the economic implications of wildfire, appropriate tools for communicating and coordinating invasive plant eradication methods, and means to quantify the value of and develop markets for ecosystem services (Bennett et al. 2019). Some research has approached these questions, but substantial knowledge gaps remain.

Management that sustains lifestyles and livelihoods, as well as the myriad species that call sagebrush home, will require solutions as diverse as the people. Considering the paucity of social science research including input from Native Nations, traditional ecological knowledge, and local knowledge, there is potential for significant improvement in sagebrush management if future research is representative of the diversity of stakeholders in the biome. Finally, we lack a clear link between social science and management implementation. While some mechanisms are in place to provide stakeholder input (e.g., NEPA public scoping), there are few requirements for inclusion or implementation of social science into ecosystem management. Future research should be focused on the development of policy and frameworks that appropriately implement social science into natural resource management. Implementing social science insights in ecosystem management and conducting biome-specific research can improve ecosystem management in rangelands and other systems globally.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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